A Study on Factors Influencing Team Human Error in Subway Traffic Dispatching Systems

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Abstract — In order to study the team human error influence factors in the subway traffic dispatching system, Delphi method was used to get nine individual error influencing factors and ten team error influencing factors as alternative factors. A questionnaire investigation of experienced subway dispatchers was carried out to get the individual and team human error influencing factors by the way to analysis entropy weights of every factor, so analysis on the human error influencing factors. The results showed that individual human error influencing factors in the subway emergency included business familiarity, knowledge experience, attention, responsibility and language standard. Team human error influencing factors included plan matching experience, negotiation collaboration ability, forecast ability and communication ability. Therefore, it is necessary to focus on these factors to prevent or reduce team human errors.

Keywords - Team human error influencing factors; Entropy weight method; Subway traffic dispatching system; Weight sorting

I. INTRODUCTION

Subway traffic dispatching system is the central nervous of metro operation. The behaviors’ reliability of the subway operation control center operator have great influence on the subway traffic organization. Therefore, researches on screening and analyzing the team and individual human error influencing factors of subway traffic dispatching system have practical significance, in order to prevent or reduce human errors in the subway traffic operation.

Recent studies of team errors were mainly concentrated on the fields of nuclear power plants and the aviation both home and abroad. Li-cao DAI [1] analyzed and discussed the team errors of the complex industrial systems. Ke-bing LIAO [2] created a team behavior model to simulate and analyze the team’s accident situation operation process. Zhi-qin HUO [3] analyzed the process and cause of the team error, and presented a suite of aviation team reliability measures. At present, the research of team human error influencing factors in the field of track traffic was not systematic enough, and was mostly concentrated in a few of human error influencing factors on the analysis and control [4-6]. Existing track traffic aspects human error influence factors analysis discussed the individual factors only. Melissa T.Baysari [7] used the human error influencing factors analysis system in aviation to identify the human error influential factors in Australian railway accidents. British rail and standards committee [8] studied the task’s human error analysis method of train driving to decrease the human error influential factors and adjust the human error probability. Jie Wang [9] presented a method which combined the SHEL model and analytic hierarchy process method to find the subway traffic dispatching human error influential factors, and can extract and assess the man–machine system’s human error influential factors fast. Jie Wang was also presented a dispatcher’s human error behavior identification method based on emergencies scenario [10]. Y.H.J.Yang [11-15] built an IDAC model which is a kind of team error situation model to realize probability forecast about the abnormal response of plant team and to quantify the relationship among the human error influential factors.

Based on this way, in this paper will determine the subway traffic dispatching team human error influential factors in accordance with subway traffic dispatching human error modes. The influential factors are divided into two categories which are the individual influential factors and the team influential factors. A questionnaire are carried out to help determine the influential factors’ weighting sort.

II. THE DETERMINATION OF SUBWAY TRAFFIC DISPATCHING HUMAN ERROR INFLUENCING FACTORS

Y.H.J.Chang presented IDAC model, mainly including information processing model, diagnosis and decision making model, and result performed model. The simulation is similar to the subway traffic dispatching team. So this article primarily identified 32 subway dispatching human error influencing factors according to the IDAC model. Here are three roles (decision makers, practitioners, consultants) human error influencing factors in the emergency response of subway traffic dispatching, TABLE I to TABLE III. (Behind said in brackets is the role of error, decision makers use D to represent, practitioners use P to represent, consultants use C to present).

TABLE I. HUMAN ERROR INFLUENTIAL FACTORS IN INFORMATION PROCESSING STAGE

<table>
<thead>
<tr>
<th>Individual Factors</th>
<th>Team Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention (P)</td>
<td>Lack of communication(D/P/C)</td>
</tr>
<tr>
<td>Responsibility (P)</td>
<td>Man-machine interface defects(D/P/C)</td>
</tr>
<tr>
<td>Understanding (P)</td>
<td>Time constraints of load(D/P)</td>
</tr>
<tr>
<td>Business familiarity (D/P)</td>
<td>Resource management defects(P)</td>
</tr>
<tr>
<td>Knowledge experience (D/P)</td>
<td>Training defects(P)</td>
</tr>
</tbody>
</table>

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III. THE ENTROPY WEIGHT METHOD TO CALCULATE WEIGHT SORTING OF HUMAN ERROR INFLUENCING FACTORS

A. The choice of human error influencing factors

In order to further research team error in the subway traffic dispatching system, using Delphi method choose ten individual and nine team influencing factors from 32 human error influencing factors. Ten individual influencing factors including attention, understanding, sense of responsibility, business familiarity, knowledge experience, language specification, self-confident degree, reaction force, operating ability, memory. Nine team influencing factors including ability to communication, time pressure, resource management, incentive mechanism, situation forecast ability, right to the gradient, resource allocation ability, negotiate cooperation, to match experience.

In order to determine the weight sorting of the human error influencing factors, according to literature, expert interviews, etc, established the questionnaires on the basis of Likert 5 subscales method. In view of the final result of Likert 5 subscales which very important is 5 points, 4 points is more important, 3 points is general, 2 points is not very important, 1 point is not important. Select all of a subway line experienced subway traffic dispatchers according to their own actual situation to assess it. Distributing 14 questionnaires, and recycling 13 effective questionnaires, Questionnaires were 92.8% efficient. Using the entropy weight method to determine the proportion of all the factors, to complete the human error due to quantitative analysis.

B. The entropy weight method

At present, there are some methods to determine the weight sorting, subjective assignment value and objective assignment value. Subject assignment value method is accordance with valuator degree to determine the weight sorting to each index subjectively, such as expert experience evaluation method, analytic hierarchy process. Objective value assignment method is based on the objective information connection intensity of original data or the information provided by the various indicators to determine the index weight [16], such as the entropy weight method, factor analysis, etc. The author thinks that, relying on subjective assignment, often different selection of experts to the big differences, makes the analysis result is not so stable; And the entropy weight method can avoid the subjectivity, while giving the weight, so the entropy weight method is chose.

The main calculation steps of entropy weight method is shown below:

1) Step one: Select n respondents to evaluating m influencing impacts in the questionnaire is \( X^i_y \), \( i = 1,2,..,n, j = 1,2,..,m \), then forming the matrix:

\[
\begin{bmatrix}
X^i_{11} & X^i_{12} & \cdots & X^i_{1m} \\
X^i_{21} & X^i_{22} & \cdots & X^i_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
X^i_{n1} & X^i_{n2} & \cdots & X^i_{nm}
\end{bmatrix}
\]

2) Step two: Calculating the i respondent, the proportion \( e^i_j \) of the j influential factor numerical value expression is:

\[
f^i_j = \frac{x^i_j}{\sum_{i=1}^{n} x^i_j}
\]

3) Step three: Put \( e^i_j \) to the entropy sorting of j influencing factor in the system, formula for:

\[
e^i_j = -\frac{1}{\ln n} \sum_{j=1}^{m} f^i_j \ln f^i_j
\]

4) Step four: According to influencing factor’s entropy sorting to determine its entropy weight, the j influencing factor’s entropy weight is expressed as:

\[
W^i_j = \frac{1 - e^i_j}{\sum_{j=1}^{m} (1 - e^i_j)}
\]

Using the entropy weight method to get the weight coefficient, reflecting the changing degree of each index in the overall index, and impact on the other indexes. The entropy weight method is adopted to the subjective assignment result of objective analysis and processing, enhance the credibility of the weight sorting. According to the above calculation method, it is concluded that the weight of influence factors as shown in TABLE IV and TABLE V.
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THE CALCULATION RESULTS OF INDIVIDUAL INFLUENTIAL FACTORS WEIGHT SORTING IN THE ENTROPY WEIGHT METHOD

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Attention</th>
<th>Understanding</th>
<th>Responsibility</th>
<th>Business familiarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.104637</td>
<td>0.099349</td>
<td>0.104163</td>
<td>0.107469</td>
</tr>
<tr>
<td>rank</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Knowledge experience</th>
<th>Language specification</th>
<th>Self-confidence</th>
<th>Reaction force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.106612</td>
<td>0.103898</td>
<td>0.096288</td>
<td>0.095173</td>
</tr>
<tr>
<td>rank</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Operating ability</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.092441</td>
<td>0.091784</td>
</tr>
<tr>
<td>rank</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

TABLE IV: THE CALCULATION RESULTS OF TEAM INFLUENCING FACTORS WEIGHT SORTING IN THE ENTROPY WEIGHT METHOD

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Ability to communication</th>
<th>Time pressure</th>
<th>Resource management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.11452459</td>
<td>0.10528</td>
<td>0.106309</td>
</tr>
<tr>
<td>rank</td>
<td>4</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Incentive mechanism</th>
<th>Situation forecast ability</th>
<th>Right to the gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.109269</td>
<td>0.11484</td>
<td>0.106276</td>
</tr>
<tr>
<td>rank</td>
<td>6</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Resource allocation ability</th>
<th>Negotiate cooperation</th>
<th>Match experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight sorting</td>
<td>0.111729</td>
<td>0.115631</td>
<td>0.116141</td>
</tr>
<tr>
<td>rank</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

C. The analysis of the subway dispatching main human error influencing factors

According to the entropy weight method, to get individual error influencing factors’ weight is among top five: business familiarity, knowledge experience, attention, sense of responsibility, and language specification. But team error influencing factors’ weight is among top four: to match experience, negotiate cooperation, situation forecast ability, and ability of communication. As you can see, business familiarity and staff’s knowledge experience is the main cause of the individual error. But to match experience and negotiate cooperation among the staffs is the main reason of the team error.

Subway dispatching job is remote monitoring and controlling, give an order through the communication tools. So it is easy to take place human error in the information processing stages (information acquisition, accident crisis awareness stage). Subway dispatchers get information from drivers and station controllers through comprehensive screen, computer and telephone. Due to the large amount of information, display mode diversity, information change fast, subway dispatcher’s workload increase greatly, therefore it is susceptible to produce human error in the diagnosis and making decision. In case of emergency, the subway dispatchers’ decision is very important to emergency rescue, will lead to human error in the same team. According to the weight sorting of the influencing factors in table 2 and table 3, specific analysis the main influencing factors influence on human error.

1) The analysis of individual error influencing factors: Every member in subway traffic dispatching team judge, decide, plan and operate for emergency situation, is decided to their respective environment, their knowledge structure, the attention of things and the influence from other individuals, as well as each member’s task is different among the traffic dispatching team. So the individual error is related to knowledge experience, business familiarity, and attention.

The production of many human errors is due to the staff’s unskilled business, business unskilled dispatchers unable to capture useful information correctly from a large of inputting information, and influence the follow-up emergency response. For the output and perform operations, business unskilled dispatchers influence the efficiency of emergency response, and may lead to faulty operation, human error explicit, causing the deterioration of the accident. Lack of knowledge experience will cause information perception error for sudden accident, thus appearing decision-making error. Inadequate experience performer will influence decision makers, and affect the efficiency of emergency response. When accident occurs, dispatchers find upload the fault information in the form of text on the monitoring system, a large of information is shown in front of the dispatchers, due to the limited attention, are more likely to ignore important information and to extend the time of rescue. Both decision makers and performers, focused attention is not enough, will cause the response command reception unsmoothly, leading to a slow efficient emergency response. Lack of sense of responsibility of the dispatcher will also ignore or omit main information, leading to the fault information is not response in time, missed the best time to emergency response. When the dispatchers receive fault information, they publish rescue information as decision makers, the dispatcher's language competence will be smooth, way of thinking to be clear, the comprehension of the fault information thoroughly, to the knowledge competence have the self-confidence, so taking rescue measures with the fastest speed, reduce the loss while accident occurs.

2) The analysis of team error influencing factors: In addition to the individual influencing factors, team collaboration is the other main factor to human error. Any individual error result from tacit understanding in the team work, poor communication between team members lead to inaccurate information, not enough unity tightness among the member, also can't form consistent goal, and will affect working mood, leading to human error. So traffic dispatching team is very important to cooperate with each others.

Team collaborative mechanism is feature of dispatching system, team members help and support each other to complete traffic dispatching assignments. But if team
cohesion is low among teams, poor safety consciousness, communication unsmooth among members, members of the connection is not tight, heterogeneous language, at the same time the division of labor is not clear, the responsibility is not specific among employees, leading to team analysis plan error, decision scheme error is set. Traffic dispatching in the process of selecting the plan and determining the scheme, the site has been in a more dynamic changes, bring uncertainty to decision maker, traffic dispatcher depend on the situation forecast ability to judge the trend of development of the accident, and have reasonable negotiate cooperation with the station and electric dispatching to formulate correct emergency plans, to prevent subsequent adjustment plan or lack of remedial measures, making the work in a passive state. When traffic dispatching communicate with the station and drivers semantic heterogeneous, leading to inaccurate understanding, contact equipment failure to miscommunication, leads to safety hazard and accident statistics analysis deviation. So we should regulate language communication as well as process steps between dispatching and other teams, often strengthen studying between positions and the ability of communication each others. When emergency occurs, traffic dispatchers must be a clear thinker, reasonably allocate resources, enables every employee to play their jobs benefit maximization. In the decision analysis, simulating every employee in dispatching teams through incentive mechanism is devoted to the decision making, reducing the partiality and limitation of decision making, ensuring the correctness of decisions.

Therefore, from the intuitive point of view, business familiarity and knowledge experience will directly influence the speed and accuracy of dealing with problems to traffic dispatchers, generating human error. While negotiate cooperation and to match experience are the most prone to team error influencing factor in dispatching system.

IV. CONCLUSION

According to the literature analysis and interviews experienced dispatchers, to get human error model of three stages easily, preliminary identification of 32 human error influencing factors from three stages with IDAC model, to get three roles (decision makers, practitioners, consultants) human error influencing factors in the emergency response of subway traffic dispatching system.

Using the Delphi method selected 10 individual error influencing factors and 9 team error influencing factors, using the entropy weight method to calculate and sort the human error influencing factors, and then analyze the results. For individuals, prone to occur error influencing factors are business familiarity and own knowledge experience; but the main team error influencing factors are negotiate cooperation and to match experience.

Research on the human error influencing factor of subway traffic dispatching also very few, so do accident case, and the data quantity is not big enough, unable to quantitative research on the human error accurately.

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REFERENCES
